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Phytochemistry and Pharmacological Actions of Ginger: An In-Depth Review

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Abstract: *Zingiber officinale* (generally known as ginger) is one of the utmost extensively employed herbs and food flavouring agents. *Z. officinale* belongs to the family Zingiberaceae which has over 1200 species in 53 genera. *Z. officinale* is widely used in traditional medicinal systems to treat a wide range of illnesses. The research includes its effects on cancer prevention, immune modulation, cardiovascular health, and pain relief. Studies also highlight its potential in managing diabetes and gastrointestinal disorders. In the last few decades, *Z. officinale* was extensively explored for its medicinal potential by innovative scientific methods and a diversity of bioactive molecules were derived from this plant and investigated pharmacologically. The present study is collective information concerning the phytochemistry and pharmacological activities of the herb *Z. officinale*.

Keywords: Ginger, Gingerols, Phytochemistry, Pharmacological actions, *Zingiber officinale*.

1. Introduction

Traditional medical systems have relied on herbs and plants as a rich source of therapeutic compounds for centuries, serving as the foundation for many modern medicines. Traditional healthcare systems, as well as the herbal and pharmaceutical industries, rely heavily on medicinal plants. The therapeutic efficacy of these medicinal plants depends on the certain bioactive chemical compounds belonging to flavonoids, alkaloids, tannins, and phenolic class which produce a significant physiological action on the human body [1-3]. *Zingiber officinale* (family: Zingiberaceae) is one of the important medicinal plants with an array of nutritional and ethnomedicinal values therefore, widely used worldwide as a flavouring agent, spice and herbal medicine. Traditionally, it is used in Africans, Arabian, Ayurveda, Caribbean, Chinese, Siddha and many other medicinal therapies for the management of a variety of diseases such as asthma, constipation, cough, dyspepsia, indigestion, inflammation, loss of appetite, nausea, pain, palpitation and vomiting. *Z. officinale* has been intensively investigated for its therapeutic potential using cutting-edge scientific methods in recent decades. In addition, a wide range of bioactive chemicals have also been extracted from different plant parts and pharmacologically analysed [4-5]. This plant has been reported to possess analgesic, anticancer, antidiabetic, anti-inflammatory, antimicrobial, antioxidant, hepatoprotective, immunomodulatory, larvicidal and nephroprotective activities [6-7].

2. Taxonomy

Kingdom: Plantae
Division: Magnoliophyta
Order: Zingiberales
Family: Zingiberaceae
Genus: *Zingiber*
Species: *Zingiber officinale*

3. Vernacular Names

Zingiber officinale is commonly known as ginger in English. Other names of *Z. officinale* in different languages worldwide are listed in **Table 1** [6].

Table 1: Vernacular names of *Z. officinale*.

Name	Language	Name	Language
Adrak	Urdu	Gingembre	French
Ada	Bengali	Ginger	English
Adarakha	Hindi	Gingimbre	Caribbean
Adi, Adrak	Punjabi	Imbir lekarski	Polish
Adu	Gujarati	Inchi	Malayalam
Aduwa, sutho	Nepali	Injee, Allam, Lakottai, Inji	Tamil
Alla, Hasishunti	Kannada	Jahe	Indonesian
Allamu, Allam	Telugu	Katubhadra, Srngavera	Sanskrit
Ardrak, Ale	Marathi	Khing	Thai
Gember	Dutch	Saenggang	Korean
Gemeiner ingber/ingwer	German	Sheng Jiang	Chinese
Gengibre/jengibre	Spanish	Shokyo	Japanese

4. Geographical Coverage

Z. officinale is widely distributed in many countries in southern and eastern Asia, including India, China, Indonesia, Nigeria, Nepal, and Thailand. As far as the growing environment is concerned, it is typically found in tropical and subtropical climates. India produced 4.1 million tonnes of ginger globally, accounting for 44 percent of the total [8].

5. Morphology

The plant has fleshy, branching rhizomes and is between 0.5 and 1 metre tall (**Figure 1**). This plant possesses a strong scent and flavour. The leaves are sessile, attenuated to thin, and lanceolate or linear-lanceolate with an acuminate apex. The bracts are oblong, light green or yellowish at the margins, and mucronate at the apex of the ovoid inflorescence. The flower is yellowish-green with lanceolate lobes, and the calyx tube is approximately 1 cm long [8].

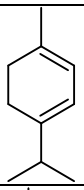
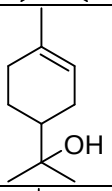
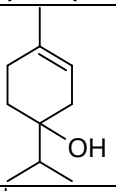
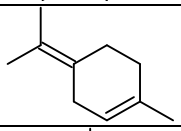
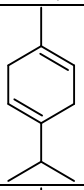
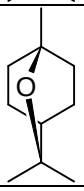
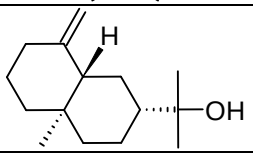
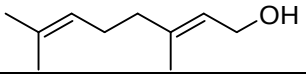
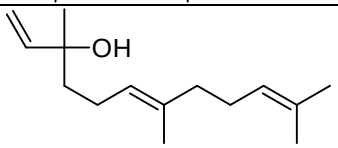
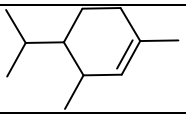
Figure 1: Morphology of *Z. Officinale* Rosce.

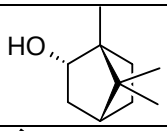
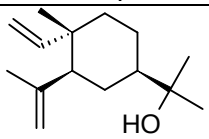
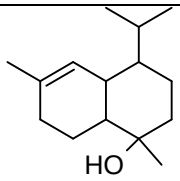
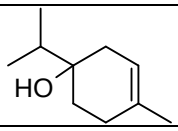
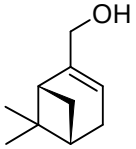
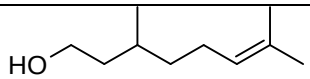
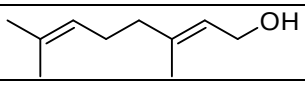
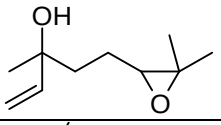
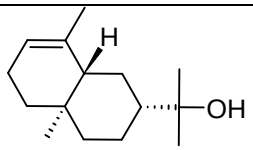
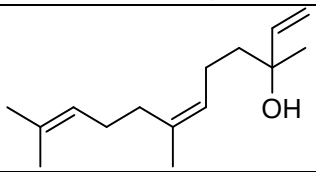
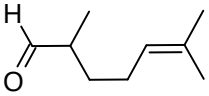
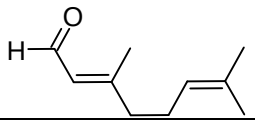
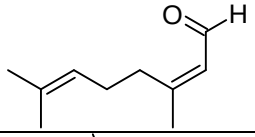
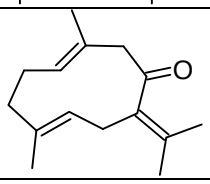
6. Phytochemistry

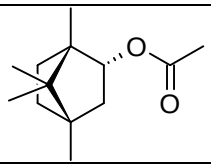
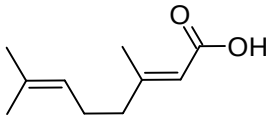
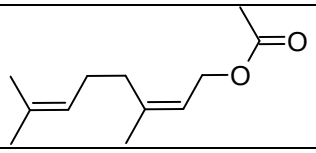
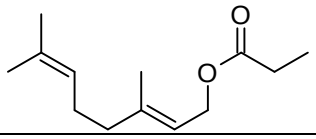
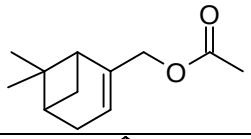
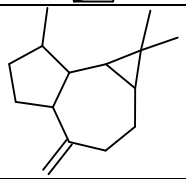
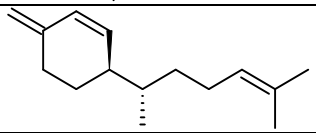
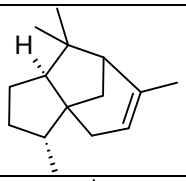
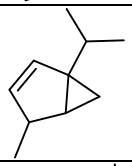
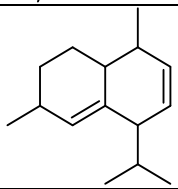
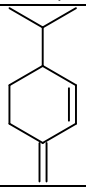
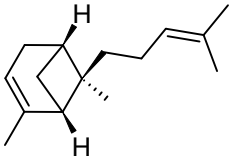
More than 100 chemical components that have been isolated from *Z. officinale* were found through a literature search. Gingerols, essential oils, diarylheptanoids, and others represented in **Table 2** make up the majority of

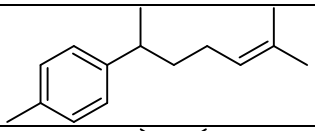
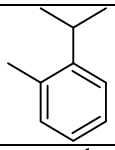
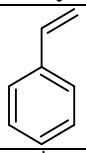
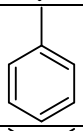
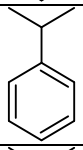
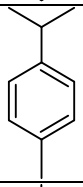
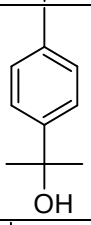
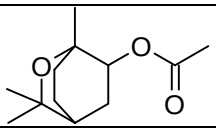
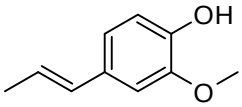
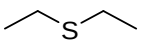
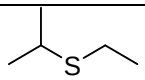
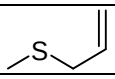
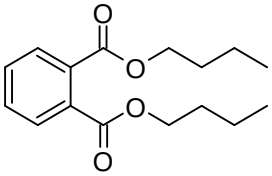
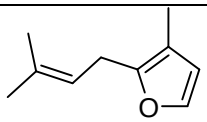
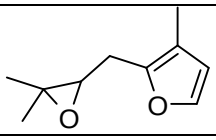
the ingredients. The blend of several compounds that make up *Z. officinale* is a pungent component, collectively known as gingerol, which includes gingerdiols, gingerdiones, shogaols, paradols and zingerone. In addition to contributing significantly to the typical spicy flavour, gingerols are also essential for several biological processes. The functional group 3-methoxy-4-hydroxyphenyl is present in the structure of gingerols [9]. Another important component of *Z. officinale* is an essential oil, which is mostly made of the compounds camphene, phellandrene and pinene [10]. The plant contains 0.25 percent to 3.0 percent essential oil overall [11]. In addition to the aforementioned, *Z. officinale* has also yielded phenylpropanoids, flavonoids, nucleosides, polysaccharides, proteins, cellulose, as well as a vast variety of carbohydrates and trace elements [12-13].

Table 2: Major phytoconstituents present in *Z. officinale*.

Chemical class	Compound	Structure	References
Terpenes	*α*-Terpinene		[14]
Terpenes	*α*-Terpineol		[14]
Terpenes	4-Terpineol		[14]
Terpenes	Terpinolene		[14]
Terpenes	*c*-Terpinolene		[14]
Terpenes	Cineole		[14]
Terpenes	*β*-Eudesmol		[14]
Terpenes	Nerol		[14]
Terpenes	*trans*-Nerolidol		[14]
Terpenes	*cis*-Piperitol		[14]

Terpenes	Borneol		[14]
Terpenes	Elemol		[14]
Terpenes	*tau*-Muurolol		[14]
Terpenes	1-Isopropyl-4-methylcyclohex-3-enol		[14]
Terpenes	Myrtenol		[14]
Terpenes	Citronellol		[14]
Terpenes	Geraniol		[14]
Terpenes	*cis*-Linalool oxide		[14]
Terpenes	*α*-Eudesmol		[14]
Terpenes	Nerolidol		[14]
Terpenes	2,6-Dimethylhept-5-enal		[14]
Terpenes	(*E*)-Citral		[14]
Terpenes	(*Z*)-Citral		[14]
Terpenes	Germacrone		[14]

Terpenes	L-Bornyl acetate		[14]
Fatty acids	Geranic acid		[14]
Terpenes	Neryl acetate		[14]
Terpenes	Geranyl propionate		[14]
Terpenes	Myrtenyl acetate		[14]
Terpenes	Bicyclo[2.2.1]heptanes		[14]
Terpenes	allo-Aromadendrene		[14]
Terpenes	*β*-Sesquiphellandrene		[14]
Terpenes	*α*-Cedrene		[14]
Terpenes	*β*-Thujene		[14]
Terpenes	Cadina-5,8-diene		[14]
Terpenes	*β*-Phellandrene		[14]
Terpenes	*α*-Bergamotene		[14]

Terpenes	*α*-Curcumene		[14]
Terpenes	*o*-Cymene		[14]
Terpenes	Styrene		[15]
Terpenes	Methylbenzene		[15]
Terpenes	Cumene		[16]
Terpenes	*p*-Cymene		[17]
Terpenes	*p*-Cymen-8-ol		[14]
Terpenes	2-Acetoxy-1,8-cineole		[15]
Terpenes	Isoeugenol		[18]
Organo-sulphur compounds	Diethyl sulphide		[16]
Organo-sulphur compounds	Ethyl isopropyl sulphide		[16]
Organo-sulphur compounds	Methyl allyl sulphide		[16]
Phthalates	Dibutyl phthalate		[19]
Furan derivatives	2-(3′-Methyl-2′-butenyl)-3-methylfuran		[18]
Furan derivatives	2-(2′,3′-Epoxy-3′-methylbutyl)-3-methylfuran		[18]

7. Ethnobotanical Uses

Ginger is crucial in the traditional Indian medicine system. Traditional Indian beverages contain it as an ingredient. Fresh ginger is one of the primary spices used in both vegetarian and non-vegetarian cuisines. Traditional medical treatment for cough and asthma consists of a mixture of fresh ginger juice, honey, and a small amount of fresh garlic juice [20]. In addition, It lessens all motion sickness symptoms, including cold sweats, nausea and vomiting [21]. It exhibits larvicidal activity and supports immune system stimulation. Furthermore, it also demonstrated antimicrobial and antioxidant potential [22].

8. Pharmacological Studies

In ayurvedic machines, ginger is used to remedy each communicable illness in addition to non-communicable illnesses. Ginger displays an exclusive pharmacological pastime (**Table 3**) which is very beneficial for the medicinal porous [23].

Table 3: Pharmacological action of *Z. officinale*.

Sr. No.	Pharmacological activity	Phytochemical	References
1	Anti-diabetic activity	6-Gingerol, gingerol, zingerone	[24]
2	Antioxidant activity	Gingerol	[24]
3	Anti-bacterial activity	6-Gingerol	[25]
4	Anti-diarrhoea activity	Zingerones, gingerols	[26]
5	Cytotoxic activity	6-Gingerol, paradol	[27]
6	Anthelmintic activity	Levamisole	[28]
7	Analgesic activity	Gingerdion	[29]
8	Anti-inflammatory activity	6-Shagaol, 6-gingerol	[29]
9	Hepatoprotective effect	Chlorogenic acid, hesperidin	[30]
10	Nephroprotective activity	Zingerone, 6-shagoal, 6-paradol	[31]
11	Larvicidal activity	Gingerol	[31]
12	Anti-tumour	6-Shogaol	[32]
13	Anti-platelet activity	Gingerol, shogaol	[31]
14	Anti-obesity	6-Shogaol, 6-gingerol	[31]
15	Gastroprotective	Zingerone	[31]
16	Asthma	Zingerone	[31]
17	Anti-emetic	6-Gingerol	[31]
18	Anti-melanogenesis	8-Gingerol	[31]

8.1. Gastroprotective effects

In addition to being a common home treatment, ginger is extremely effective in treating a wide range of gastrointestinal conditions, such as belching, bloating, constipation, dyspepsia, epigastric discomfort, gastric ulcerations, gastritis, indigestion, nausea and vomiting. In animal experiments, ginger has also been found to be successful in preventing stomach ulcers. Additionally, numerous preclinical and clinical investigations have demonstrated that ginger has antiemetic properties against various emetogenic stimuli. However, conflicting results particularly in the management of chemotherapy-induced motion sickness, nausea and vomiting prevent us to make any clear conclusions on its effectiveness as a broad-spectrum antiemetic. Free radical scavenging, antioxidant, and lipid peroxidation inhibitory activities of ginger have been demonstrated, and these properties may have contributed to the observed gastroprotective benefits [32-33].

8.2. Anti-inflammatory activity

Ginger extracts had been previously confirmed through laboratory *via* the experimental version of rheumatoid arthritis, streptococcal mobileular wall (SCW) inflammatory results of ginger`s different secondary metabolites. Ginger essential oils avoided acute segments of joint swelling nor granuloma development at sites of SCW deposition in the liver. Pharmacological doses of 17-β estradiol elicited inflammation suggesting that essential oils might be performing as a phytoestrogen [34-38].

8.3. Antibacterial activity

The antibacterial potential of ginger essential oils was assessed by agar well diffusion and micro-broth dilution method on fish-borne pathogenic bacteria. In addition, the evaluation of *Z. officinale* and sweet orange (*Citrus sinensis*) revealed that *Bacillus subtilis* is the bacteria that is most susceptible to ginger extract. However, the essential oils failed in the impairment of *Aeromonas hydrophile* and *Vibrio parahaemolyticus*. Furthermore, Antibiotic-resistant *Yersinia enterocolitica* was found to be the most sensitive bacterial strain among tested gram-negative bacteria [39-41].

8.4. Anti-diabetic activity

Many species of the Zingiberene family, of which ginger is a part, are regularly reported for their anti-diabetic and hypoglycemic potential. According to research, ginger increases insulin sensitivity, action, and peripheral glucose utilisation *via* having regenerative effects on pancreatic cells. Other mechanisms include boosted hepatic expression of glycogen-regulating enzymes, decreased activity of carbohydrate-metabolizing enzymes, induced pancreatic insulin release, and reduced hepatic glucose generation [42-44].

8.5. Anti-asthmatic

Ginger has been widely utilised in traditional medicine for the effective management of respiratory disorders. The ethanolic and aqueous extract of ginger rhizomes along with methylprednisolone were studied for the evaluation of anti-asthmatic activity in different animal models. Electrophoresis and ELISA were used for the evaluation of mRNA expression levels and protein levels of Th2-type markers, respectively. The ethanolic extract showed significant anti-asthmatic activity in mice [45].

8.6. Anti-fungal activity

Many common herbs have antimicrobial action because of their bioactive components, and several of them have emerged as novel potential anti-infective medicines. Only 0.3 % (*v/v*) concentration of ginger oil displayed complete inhibition against *Alternaria panax, Botrytis cinerea, Cylindrocarpon destructans, Fusarium oxysporum, Sclerotinia sclerotiorum*, and *Sclerotinia nivalis*. The findings of this study provide evidence that ginger essential oil is a potentially abundant source of natural antibiotics and may be used as an alternate anti-infective medication to combat the fungi that cause ginseng root rot [46-47].

8.7. Antioxidant activity

Ginger showed significant anti-oxidant activity by inhibiting cyclooxygenase and lipoxygenase metabolites along with arachidonic acid. In addition, both shogaol and dehydroshogaol reduce NO production by inhibiting the LPS stimulated macrophages [48-50].

8.8. Anti-diarrheal activity

Ginger's antimicrobial profile and impact on the virulent epithelial cell colonisation and enterotoxemia of diarrheal pathogens were studied. *Z. officinale* didn't exhibit any antibacterial properties. Nevertheless, it prevented the synthesis of cholera toxin. However, there was a decline in the bacterial colonisation of HEp-2 cells. These findings suggested that *Z. officinale* affects bacterial and host cell metabolism to exert its anti-diarrheal effect [26, 51].

8.9. Cytotoxic activity

According to experimental research, 6-gingerol and 6-shogaol, two of the active components of ginger, have anticancer properties that are effective against gastrointestinal cancer. The anticancer potential of ginger is thought to be its capacity to modulate several signalling molecules, including NF-κB (Nuclear factor kappa B), STAT3 (signal transducer and activator of transcription 3), Nrf2 (nuclear factor erythroid 2-related factor 2), PI3K (phosphatidylinositol-3-kinase), MAPK (mitogen-activated protein kinase), Akt (Ak strain transforming), ERK (extracellular signal-regulated protein kinase) 1/2, TNF-α (tumour necrosis factor α), β-cell lymphoma protein 2 (Bcl-2)-associated X (Bax), COX-2 (cyclooxygenase-2), SAPK/JNK (stress-activated protein kinase /jun amino-terminal kinase), cyclin D1, CDK (cyclin-dependent kinase), MMP-9 (matrix

metalloproteinase-9), BIRC5 (surviving), cIAP-1, XIAP (X-linked inhibitor of apoptosis), caspases-3, -9, p53, and other proteins regulating cell growth [52-53].

8.10. Anti-helminthic activity

Dried rhizomes of *Z. officinale* Roscoe and crude aqueous extract of the dried ground rhizomes showed anti-helminthic activity *in vitro* [54].

8.11. Hepatoprotective effect

Methanolic extract from ginger significantly restored the carbon tetrachloride-induced changes in the biochemical and cellular constituents of blood. The main active constituents of the methanolic extract of ginger include alkaloids, carbohydrates, glycosides, tannins, flavonoids, saponins, unsaturated sterols and triterpenes. The histological analysis of liver tissue also supported the hepatoprotective activity of ginger extract [55].

9. Conclusions

Ginger and its chemical constituents play a vital role in herbal and medicinal action in both communicable and non-communicable diseases. Ginger is nowadays widely used as herbal medicine and also, and it's taken in the form of dietary supplements. Ginger was used as a herb product from ancient times. Different pharmacological actions of ginger were reported including anti-asthma, anti-emetic, antihypertension, antifungal, antibacterial, and other various effects. Ginger is also reported for its anti-oxidant, anti-tumour, anti-apoptosis, and anti-inflammatory actions.

Conflicts of Interest

The authors declare no conflict of interest.

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